ERDC/CERL TR-12-19

Construction Engineering Research Laboratory

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Center for the Advancement of Sustainability Innovations (CASI)

Energy and Greenhouse Gas Emission Reduction Opportunities for Civil Works Projects Unique to the US Army Corps of Engineers

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Final Report

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Abstract

Executive Order (EO) 13514, *Federal Leadership in Environmental, Energy, and Economic Performance* expanded on the energy reduction and environmental performance requirements of EO 13423, *Strengthening Federal Environmental, Energy, and Transportation Management*. EO 13514 requires Federal agencies to set a Scope 1 and 2 greenhouse gas (GHG) emission reduction goal for fiscal year 2020 (FY20) based on an FY08 baseline. US Army Corps of Engineers (USACE) Civil Works projects include many common facility energy consumers such as office space, laboratory space, and visitor centers that are the focus of energy and GHG reduction strategies by many organizations. These “Goal Subject” (GS) energy consuming facilities support building operations, and do not include outdoor lighting, or facilities such as locks and dams, which are termed “Goal Excluded” (GE) facilities. USACE has many GE and non-building GHG emission sources such as those found at locks and dams; hydropower facilities; large pumping plants; fish barriers; canals, channels, harbors, and other navigation waterways; as well as docked vessels. This report documents a data analysis of GE energy consumption and GHG emissions and opportunities for reducing energy usage and GHG emissions based on site visits to three of these Civil Works project types.

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Preface

This study was conducted for Headquarters, US Army Corps of Engineers (HQUSACE) under CASI Project, “Sustainability Planning and Analysis.” The technical monitor(s) were Antonia Giardina, USACE Sustainability Program Manager and John Coho, Senior Advisor for Environmental Compliance.

The work was performed by the Environmental Processes Branch (CN-E), Installations Division (CN), and the Energy Branch (CF-E), Facilities Division (CF), Construction Engineering Research Laboratory (CERL). Deborah R. Curtin is Chief, CN-E, and Franklin H. Holcomb is Chief, CF-E. The Director of CASI is William D. Goran, and Michelle J. Hanson is the Associate Director. The Director of ERDC-CERL is Dr. Ilker R. Adiguzel.

CERL is an element of the US Army Engineer Research and Development Center (ERDC), US Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Kevin J. Wilson, and the Director of ERDC is Dr. Jeffery P. Holland.

1 Introduction

1.1 Background

Executive Order (EO) 13514, *Federal Leadership in Environmental, Energy, and Economic Performance* (5 October 2009) expanded on the energy reduction and environmental performance requirements of EO 13423, *Strengthening Federal Environmental, Energy, and Transportation Management* (26 January 2007). EO 13514 requires Federal agencies to set a Scope 1 and 2 greenhouse gas (GHG) emission reduction goal for fiscal year 2020 (FY20) based on an FY08 baseline. US Army Corps of Engineers (USACE) Civil Works projects include many common facility energy consumers such as office space, laboratory space, and visitor centers, which are the focus of energy and GHG reduction strategies by many organizations. These "Goal Subject" (GS) energy consuming facilities support building operations, and do not include outdoor lighting, or facilities such as locks and dams, which are termed "Goal Excluded" (GE) facilities. USACE has many GE energy consumers such as those found at locks and dams; hydropower projects; large pumping plants; fish barriers; canals, channels, harbors, and other navigation waterways; as well as docked vessels. This work was undertaken to analyze GE energy consumption and the associated GHG emissions at three Civil Works projects, and to identify opportunities for reducing energy usage and GHG emissions based on visits to those sites.

Reducing GE energy consumption and the associated GHG emissions will be an important part of USACE strategy for GHG emission reduction. The emissions account for slightly over half of USACE's non-mobile energy consumption and GHG emissions. For USACE as a whole, 97,370 MT CO2e emission reductions from FY2010 values are required to meet the Scope 1 and 2 goals. Meeting the energy intensity goal, the NTV petroleum goal, and the floating plant goals will reduce emissions by 31,011 MT CO2e, 24,012 MT CO2e, and 6,552 MT CO2e, respectively. This leaves 35,759 MT CO2e in Scope 1 and 2 GHG emission reductions that must still be reduced. These reductions can be achieved in any of the emission source categories, but a likely source of the reductions would be projects with Goal Excluded energy consumption.

1.2 Objective

The objectives of this work were to analyze GE energy consumption and GHG emissions across USACE and at three Civil Works projects, and to identify opportunities for reducing energy usage and GHG emissions at these types of sites.

1.3 Approach

Energy use and GHG emissions of USACE GE project facilities were analyzed to determine USACE-wide results and the types of GE facilities that would present the greatest reduction opportunities. This analysis was based on data drawn from the Corps of Engineers Reduced and Abridged FEMP Tool (CRAFT) spreadsheet submissions. The USACE-wide results were used to focus site visits where specific GE energy consumption and GHG emission reduction opportunities were examined.

The site types selected for visits were:

- *Pumping Stations*, due to their relatively large individual energy use
- *Locks and Dams*, because they are numerous and, as a group, large energy users
- *Repair Facilities*, because they use a fair amount of energy on an individual project basis.

1.4 Scope

While the findings and recommendations in this document apply broadly to all Corps of Engineers' GE facilities, the scope of site types selected for this study includes:

- *Pumping Stations*, due to their relatively large individual energy use
- *Locks and Dams*, because they are numerous and, as a group, large energy users
- *Repair Facilities*, because they use a fair amount of energy on an individual project basis.

1.5 Mode of technology transfer

This report will be made accessible through the World Wide Web (WWW) at URLs:

http://www.cecer.army.mil

http://libweb.erdc.usace.army.mil

2 Review of CRAFT Data

The CRAFT data were analyzed to provide insights into the extent and nature of GE facility energy consumption and GHG emissions within USACE. The facility energy data reported in CRAFT is categorized as either GS or GE, based on field-level determinations made in accordance with Federal Energy Management Program and USACE guidance. The data that were analyzed included all CRAFT FY08 and FY10 data; Tableau Software was used to visualize energy consumption and GHG emission results.

USACE data for FY10 show that approximately 1,519,000 MMBTU of facility energy were consumed; of that, 825,000 MMBTU were categorized as GE and 694,000 MMBTU were categorized as GS. This corresponds to total facility GHG emissions of approximately 209,000 metric tons CO_2e ($MTCO_2e$), of which 113,000 $MTCO_2e$ were emitted from GE facilities and 96,000 $MTCO_2e$ were emitted from GS facilities. From both an energy consumption and GHG emission standpoint, GS and GE results are comparable, with GE energy consumption and GHG emissions being somewhat larger. FY10 GHG emissions from GE energy consumption (referred to hereafter as “GE GHG emissions) were generated predominantly from electric energy consumption (86% of emissions), followed by diesel fuel consumption (10% of emissions), and natural gas/liquid petroleum gas (LPG) (4% of emissions). Figure 1 shows Tableau Software results for USACE MSCs GE GHG emissions. MVD, ERDC, and NAD (including Washington Aqueduct) account for almost 80% of the GE GHG emissions.

To determine individual project contributions to USACE GE GHG emissions, a spreadsheet was created from summarized CRAFT data that included information from projects with GE energy consumption. The LRC Fish Dispersal Barriers project was added to this spreadsheet since it was believed that its energy consumption should also be categorized as GE. The total USACE GE GHG emissions with this addition were about 118,000 $MTCO_2e$. Since CRAFT spreadsheet users categorized facility energy consumption, other similar categorization errors may have occurred.

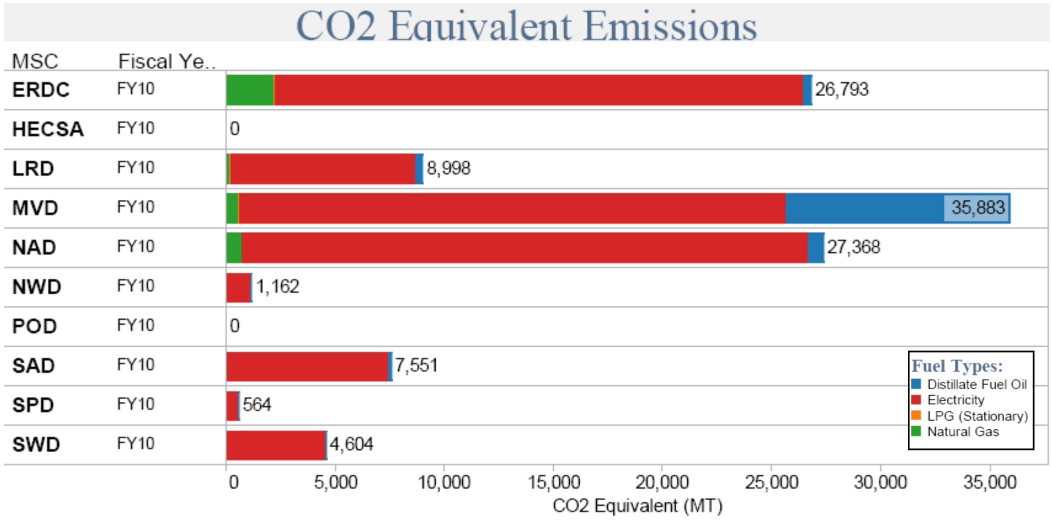

Figure 1. Major Subordinate Command (MSC) goal excluded GHG emissions.

Since the CRAFT data included individual rows for electricity and stationary combustion energy consumption, a pivot table was created to sum all GE energy consumption and GHG emissions for each project for both FY08 and FY10. Table 1 lists energy consumption and GHG emission results for the top 20 GE GHG emission sources. Although there were 318 FY10 GE projects listed, the top 20 accounted for slightly over 72% of the GE GHG emission total for USACE.

Table 1 also lists many of the types of projects expected to include GE energy consumption, including:

- two unique individual projects (Washington Aqueduct and Fish Dispersal Barriers)
- ERDC R&D laboratories (i.e., ERDC-Vicksburg [also known as the "Waterways Experiment Station," or "WES"], and the Cold Regions Research and Engineering Laboratory [CRREL])
- pumping plants (e.g., Huxtable Pumping Plant and Lake Chicot Pumping Plant)
- maintenance and repair facilities (e.g., Ensley Engineer Yard and Pittsburgh Engineer Warehouse and Repair Station)
- locks and dams (e.g., MVS Rivers Project - Lock 27 and MVR Lock 20).

Some projects in the top 20 list may actually be compilations of several emission sources reporting on a single CRAFT spreadsheet (e.g., Tenn-Tom Waterway OPCO and SAM_BWT Tuscaloosa).

Table 1. Top 20 USACE GE GHG emission sources.

	Project Name	Energy Consumption (MMBTU)	GHG Emissions ($MTCO_2e$)
1	NAB_Washington Aqueduct	186,863	26,382
2	WES_ERDC-Vicksburg	203,373	24,171
3	MVM_St. Francis River and Tributaries Maintenance (MR&T) - W.G. Huxtable Pumping Plant	84,678	6,324
4	LRC_Dispersal Barriers	23,481	4,825
5	MVK_Lake Chicot Pumping Plant	31,607	4,301
6	SAM_Tenn-Tom Waterway OPCO – MS	17,832	3,599
7	MVK_Tensas Cocodrie Pumping Plant	11,545	2,525
8	MVM_White River Backwater, AR (MR&T) - Graham Burke Pumping Plant	32,052	2,396
9	CRREL_ERDC-CRREL-NH	21,169	2,385
10	MVS_Rivers Project-Melvin Price L&D and National Great Rivers Museum (NGRM)	8,032	1,863
11	MVM_Ensley Engineer Yard	11,440	1,835
12	SAM_Tenn-Tom Waterway OPCO – AL	6,377	1,270
13	LRP_Monongahela River	5,885	1,086
14	MVS_Rivers Project - Locks 27	3,761	920
15	LRP_Pittsburgh Engineer Warehouse and Repair Station	4,408	896
16	LRP_Ohio River	4,293	882
17	SAM_BWT Tuscaloosa	3,919	780
18	MVN_Pointe Coupee Pumping Station	9,898	735
19	SWT_Truscott	4,137	731
20	MVR_Miss LD 20	3,056	713

Another data analysis was performed to determine the types of projects with GE energy consumption. The first step in this analysis was to assign each project a “project type.” Table 2 lists project type categories and the GE energy consumption and GHG emissions for each type. The project type list was developed based on the missions and functions performed by the 318 projects showing GE energy consumption in FY10. Assigning project types was based on the project name entered on the CRAFT spreadsheets and information found on USACE internet sites. Lock and dam and pumping plant projects have mostly a single activity type generating GE GHG emissions. However, while many of the other projects have multiple missions and activities, it was not always clear which mission or activity was responsible for the bulk of the GE GHG emissions. For example, most recreation sites also have a flood control mission and many hydropower generating dams also provide recreational opportunities. In each of these cases, an attempt was made to determine the primary mission of the project. The navigation category included projects such as canals and inland waterways. For the most part, projects with the word “office” included in the project name were assigned to the Office category. Please note that, if projects reported any GE energy consumption, this consumption is accounted for in Table 2. This is true even when the majority of the energy consumption at individual projects is GS. This is the reason project types such as Recreation and Office are included in Table 2.

Table 2. FY10 USACE GE energy consumption and GHG emissions by project type.

Type	Count	Energy Consumption (MMBTU)	GHG Emissions ($MTCO_2e$)
Laboratory	3	225,509	26,793
Water Treatment	1	186,863	26,382
Fish Barrier	1	23,481	4,825
Lock and Dam	83	104,094	20,092
Pumping Plant	12	186,239	17,828
Recreation	169	64,138	10,871
Navigation	9	28,941	5,776
Maintenance and Repair	6	19,886	3,452
Flood Control	19	4,321	639
Office	10	4,387	584
Hydropower	5	2,885	504

ERDC R&D laboratories, the Washington Aqueduct, and the electric fish dispersal barrier are very specialized facilities within USACE. These three laboratory and two project locations account for 47% of all GE GHG emissions and therefore represent an opportunity for reductions. However it is unlikely that reduction strategies for these projects could be applied to the rest of USACE because of the specialized nature of the missions and activities.

The three project sites selected from the GE top 20 list (Table 1) for site visits were:

1. MVM_St. Francis River and Tributaries Maintenance (MR&T) - W.G. Huxtable Pumping Plant
2. MVM_Ensley Engineer Yard
3. MVS_Rivers Project - Locks 27.

These sites were selected because they were on the top 20 list, they are members of large GE project type categories, and they were relatively close to each other. ERDC laboratories, the Washington Aqueduct, and the fish barrier were not considered due to their specialized missions.

3 Site Visits

Three sites were visited to get a firsthand look at the various energy consumers, to discuss potential energy savings opportunities with operational personnel, and to gather information to accomplish the following goals:

- *Determine an energy consumption profile*. General information was collected on the project as a whole, and more specific information was gathered on the GE (non-building) energy consumers. Researchers gathered information on individual pieces of equipment (age and efficiency) and the frequency of their use, and also determined if the site performed any separate metering of energy consumption.
- *Determine the energy consuming equipments usage*. Operation personnel were interviewed to find out how and when the equipment is used to provide an accurate understanding of equipment operation.
- *Develop energy reduction ideas*. During the site visits, researchers canvassed project personnel for their ideas on reducing energy usage or reducing greenhouse gas emissions, e.g., equipment replacement, changes in processes, more efficient operations, and fuel switching.

3.1 Lock 27

Located in Granite City, IL, Lock and Dam 27 is part of the Upper Mississippi River Nine Foot Navigation Project (Figures 2–4). The Project, which was authorized by the Rivers and Harbors Act of 1930, created and ensured a 9-ft deep navigation river channel. On the Upper Mississippi River, a total of 29 lock and dam systems were constructed, forming a stairway of water from Minnesota to Illinois. From the first lock and dam at Minneapolis-St. Paul, MN to the last one at Granite City, IL, there is a drop in elevation of 420 ft. The locks are necessary at each of the dams to allow boats to navigate from one pool (the water backed up behind each dam) to the next. These dams were constructed to aid only navigation; they were not designed for flood control. On the Lower Mississippi River, there is no need for locks and dams because, with the addition of the Missouri, Illinois, Arkansas, Ohio, and other rivers, it is naturally deep enough and wide enough for navigation.

Figure 2. Lock 27 entrance sign.

Figure 3. Miter gate.

Figure 4. Lift gate.

3.1.1 Technical details

The technical details of Locks and Dam 27 are:

- main lock chamber: 110 ft wide by 1200 ft long
- auxiliary lock chamber: 110 ft wide by 600 ft long
- average lift of lock: 15 ft
- dam length: 2500 ft
- pool length: 15.6 miles
- pool size: 489 acres (Canal only)
- tonnage locked through:
  - 2005: 68,369,897
  - 2006: 73,362,106
- Upper Mississippi River Mile: 185.5
- gate operations (cuts) 2010: 8428.

3.1.2 The Chain of Rocks Canal

In 1940, the Chain of Rocks Reach was the only obstacle that prevented the success of the 9-ft navigation project. This 17 mile stretch of the river was rife with rock ledges that rendered it naturally unnavigable. The Corps built the 8.4 mile long Chain of Rocks Canal to bypass this portion of the river.

Locks and Dam 27 is unique for several reasons. Constructed between 1946 and 1953, these locks are the only locks on the Upper Mississippi River that are not directly attached to their respective dam. The dam is located several miles away on the river, whereas the locks are within the Chain of Rocks Canal. The dam itself is also unlike any of the other dams in the system. All other dams in the system were built to be moveable, so they could be adjusted according to the changing water level. Dam 27 is not so complex; it is a 2500-ft non-movable low water dam extending across the river. Its main purpose is to help maintain the lower pool of Dam 26 and to prevent boats from entering the Chain of Rocks Reach.

Both the main lock and the auxiliary lock have an upper lift gate and lower miter gates. The lift gates lower to a predetermined depth to allow boats to pass over. The miter gates swing open and closed like doors to allow the boats through. Since these locks are the last on the upper Mississippi they lock the most commercial traffic. This is why Locks and Dam 27 has two lock chambers, of which the main lock can accommodate a full tow of 15 barges (3 wide by 5 long).

3.1.3 Locking process

The lock chambers consist of two miter gates, one vertical lift gate, and four valves (two at each end). All boats wishing to pass through a dam must lock through the lock chamber, even during open river conditions when there is only a 10- or 12-in. difference between the upper and lower pools.

Lockage is completed by using a system of valves to raise and lower the water level in the lock chamber. The filling valves are opened to allow water to enter the chamber, making it the same height as the upper pool. The emptying valves are opened to allow water to drain out, making the chamber the same height as the lower pool. There are two sets of valves, the filling valves (located at the upper pool) and the emptying valves (located at the lower pool). During the process, no pumps are used; the chamber is operated solely on gravity (Figure 5). A low flow electrical generation device could theoretically be installed in the filling valve area of the piping; however this would slow the filling process. It is not known if this has ever been done nor how well it would work—but it may be worth further investigation.

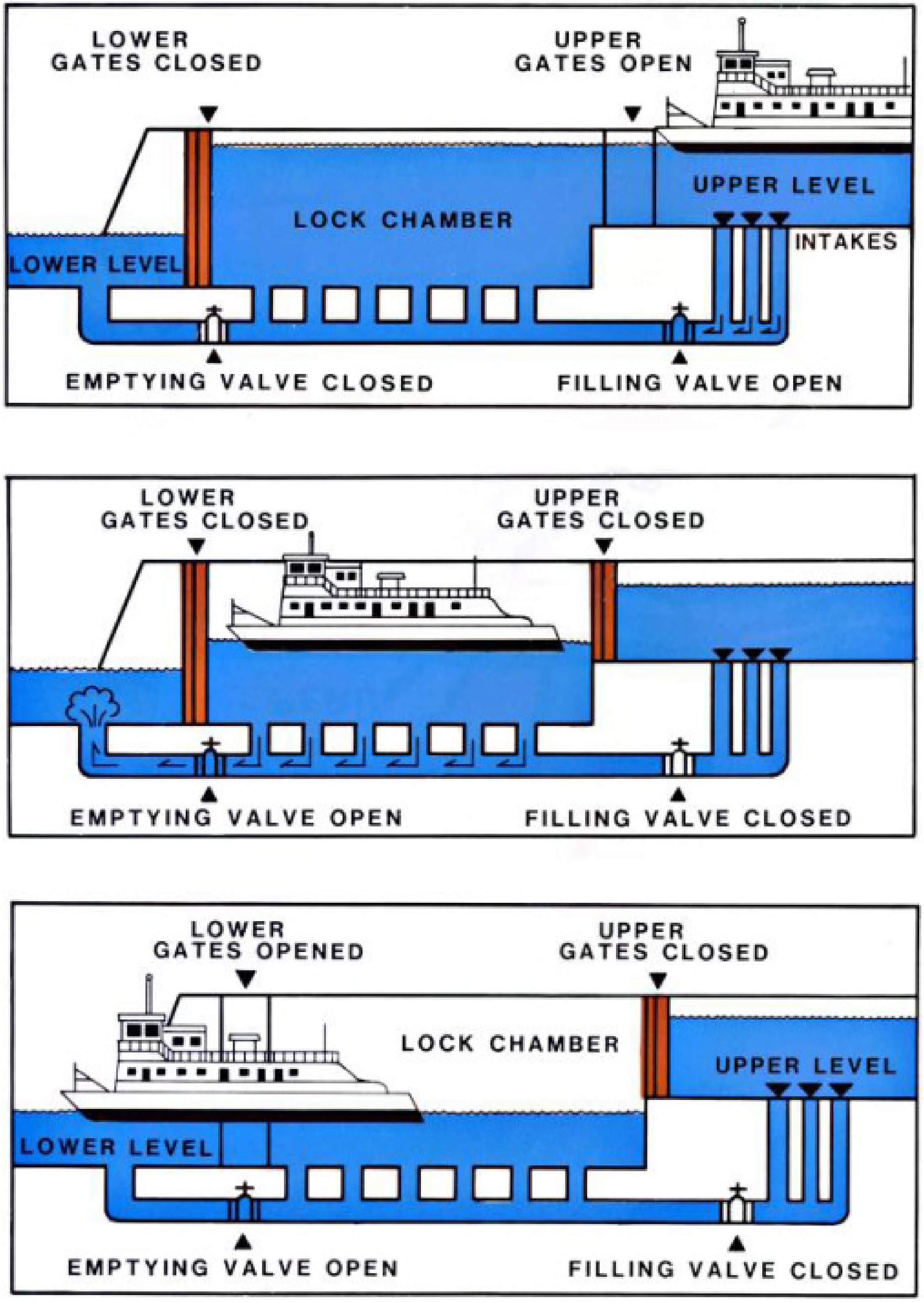

Figure 5. Locking process diagram.

3.1.4 Energy consumption

All energy used at Lock 27 is either electrical or diesel fuel (backup emergency generators). There is no natural gas consumption. Both the FY08 and FY10 CRAFT spreadsheet reported all GE electricity use. The FY08 usage was 993,511 kWh (830 $MTCO_2e$) and the FY10 usage 1,101,864 kWh (920 $MTCO_2e$).

3.1.5 Electric motors

The major GE energy consumers are the electric motors associated with the movement of gates and valves. Table 3 lists the motors, their use, performance properties, and time of operation during a single locking sequence, at both the Main Lock Chamber and the Auxiliary Lock Chamber. Therefore, only half of the motors shown in the table that are part of locking operations are used during each lockage event. The times shown in the table are to either move a boat into or out of one of the lock chambers.

The 100 hp liftgate motors use a variable frequency drive so that the gates can be operated at the desired speed depending on the operation being performed. An interesting feature is a resistance bank that is used to keep the motor from spinning too fast. Presumably this is required to counteract the weight of the gate while being lowered. If a use of or means for storing this electrical energy could be found, it might yield significant savings. Drawings of the resistance bank were not available at the time of the visit. When available a review of these drawings would be appropriate to evaluate potential opportunities.

Table 3. Electric motors used for lock operations.

Motor Use	Size	Number	Efficiency	Time of Operation Per Event Min:Sec
Downstream Lift	100 hp	4	94.1	1:33
Walkway	30 hp	4	92.4	Unknown
Upstream Gate	15 hp	4	91	1:50
Culvert	10 hp	6	Unknown	
Minor Gate	50 hp	6	92.4	Open 3:28 Close 4:21
Hydraulic Pilot Pump Miter	10 hp	6	Unknown	Open 3:28 Close 4:21
Fill Valve Motors	20 hp 35 hp	3 1	Unknown	1:33
Empty Valve Motors	20 hp 35 hp	3 1	Unknown	1:33

3.1.6 Energy conservation measures

A common Energy Conservation Measure (ECM) for motors is replacement with more efficient ones. Table 4 lists efficiency levels required to meet the National Electrical Manufactures Association (NEMA) requirements for an enclosed motor to be labeled Premium Efficient. These specifications would also generally apply for open motors. In this case, the motors are already very close to "premium" efficiency levels. At best a 1.4% improvement might be achieved. The savings for the largest motor would be:

Savings = 100 hp x 8428 x 2 operations x 1.55 min x 1hr/60min x 0.746kW/hp x (1 – [0.941/0.954]) = 443kWh (0.37 $MTCO_2e$)

These savings would yield about $33/yr, not enough to justify the cost.

In building systems, one tends to also look for measures that can reduce run time. In the case of a lock system, motor operation is essential to its mission so reducing motor run time is not a feasible ECM. One could attempt to reduce the number of operations, but once again this is already done to the extent possible.

Table 4. Full-load efficiencies for 60HZ NEMA Premium® efficiency electric motors.

ENCLOSED MOTORS						
	2 POLE		4 POLE		6 POLE	
hp	Nominal Efficiency	Minimum Efficiency	Nominal Efficiency	Minimum Efficiency	Nominal Efficiency	Minimum Efficiency
1	77.0	74.0	85.5	82.5	82.5	80.0
1.5	84.0	81.5	86.5	84.0	87.5	85.5
2	85.5	82.5	86.5	84.0	88.5	86.5
3	86.5	84.0	89.5	87.5	89.5	87.5
5	88.5	86.5	89.5	87.5	89.5	87.5
7.5	89.5	87.5	91.7	90.2	91.0	89.5
10	90.2	88.5	91.7	90.2	91.0	89.5
15	91.0	89.5	92.4	91.0	91.7	90.2
20	91.0	89.5	93.0	91.7	91.7	90.2
25	91.7	90.2	93.6	92.4	93.0	91.7
30	91.7	90.2	93.6	92.4	93.0	91.7
40	92.4	91.0	94.1	93.0	94.1	93.0
50	93.0	91.7	94.5	93.6	94.1	93.0
60	93.6	92.4	95.0	94.1	94.5	93.6
75	93.6	92.4	95.4	94.5	94.5	93.6
100	94.1	93.0	95.4	94.5	95.0	94.1
125	95.0	94.1	95.4	94.5	95.0	94.1

Any further reduction would result in increased wait times, which is unacceptable for commercial operations. Recreational craft could be limited to specific times of the day to reduce lock operation, but this too would likely be seen as unacceptable.

3.1.7 Exhaust fan motors

There are five ¾ hp exhaust fan motors used for drying out the lower cavity of the lock. Their efficiency is unknown, but they appear to be old and are likely of low efficiency. They run approximately 8 hours a day on average. Motors of this size that are not high efficiency are typically in the range of 78% efficient. A premium motor could be as much as 82% efficient. The savings achievable by motor replacement may be calculated as:

Savings = 0.75 hp x 0.746kW/hp x 8hr/day x 365 day x (1 – [0.78/0.82]) = 80 kWh/yr (0.07 $MTCO_2e$)

These calculated savings translate to $6/yr. The payback time in terms of energy savings is cost prohibitive. However on motor failure, replacement with a high efficiency motor is recommended.

3.1.8 Emergency generator

A 750 kW diesel fueled Caterpillar generator (Figure 6) is occasionally used for backup power. No feasible ECMs were found for the generator.

3.1.9 Air compressors

Two 2008 vintage Boge SF 150 480V 174 Amp (145 hp) air compressors (Figure 7) are used for bubbling air near the gates to break up ice in the winter, principally December through February. Only one is operated at a time. The bubblers are operated only when opening and closing the gates. There is also a smaller 20 hp compressor, which is used principally to power pneumatically operated hand tools.

When the temperature of compressor is 32 °F or less, the compressor controls run the compressor to keep it warm regardless of air pressure needs. The shelter that they are in has heaters, but the shelter has virtually no insulation. Run time could be significantly shortened by insulating the shelter. The cost of doing this would vary depending on the insulation method chosen. Insulating the external side of any existing building is preferred to insulating the interior.

Figure 6. Lock 27 backup generator.

Figure 7. Lock 27 bubbler air compressor.

One option for the walls is the External Insulation Finishing System (EIFS), which can be made to look like any desired surface. However its cost is approximately $12/sq ft for a 2-in. thickness and R value of 20.6. The ceiling and walls could both be easily spray foamed with a closed cell foam for about $2.5/sq ft. The shelter is approximately 10x20x12 ft, or 920 sq ft. The cost would be about $2300. The rollup door may also need replacement with an insulated one. Based on Engineering Weather Data for the St. Louis airport provided by Air Force Weather Services, the temperature is below 32 °F for 1444 hours per year.

Savings are difficult to determine because the part load operating condition energy consumption is unknown. The following calculation assumes a conservative estimate of 20% full load, and a 30% duty cycle run time for keeping the compressor warm:

Energy use = 145 hp x 0.20 x 1444 hrs/yr x 0.30 x 0.746kW/hp = 9372 kWh/yr (7.83 $MTCO_2e$ /year)

At a cost of $0.075/kWh this is worth nearly $800/yr providing a 2.9 year payback.

3.1.10 Outdoor lighting

Outdoor lighting is provided by 16 masts with five fixtures per mast (Figure 8). Each fixture has a 1kW high pressure sodium lamp (HPS) for a total lighting load of 80kW. This fixture type is not the most efficient available. Currently available fluorescent and light emitting diode (LED) fixtures use a fraction of the energy consumed by an HPS. A more detailed study would be required to determine the number of fixtures required and estimated savings.

3.1.11 Building lighting

As with any building, those at Lock 27 have lighting and Heating Ventilating, and Air Conditioning (HVAC) equipment consuming devices. The indoor lighting is used both for office environments (GS) and for the lock structure (GE). There are approximately 300, 26W compact fluorescent lights in the lower walkways (Figures 9 and 10), which are on 24 hours a day 365 days a year that could be put on occupancy sensors.


Figure 8. Mast lighting at Lock 27.


Figure 9. Lock 27 hallway lighting.


Figure 10. Lock 27 Lower hallway lighting.

Due to the long length of the hallways, it is suggested that lights be connected to occupancy sensors in groups of 10 to 13 lights per sensor. With an estimated runtime of 1 hour per day, savings are calculated as:

Savings = 300 lights x 26W x 23hr/day x 365 day/yr x 1kW/1000W = 65,481 kWh/yr (54.7 $MTCO_2e$ /yr)

At an average cost of $0.075/kWh, the installation of occupancy sensors would yield savings of $4911/yr. Assuming an average of 12 lights per sensor, the installation would require 25 sensors. The cost of installing the sensors and re-wiring of the lights would be approximately $300 per sensor for a total cost of $7500. Simple payback would occur in 1.5 years.

3.2 Ensley Engineer Yard

3.2.1 Description

Ensley Engineer Yard (Figure 11) is located 8 miles southwest of downtown Memphis, TN, covering 157 acres on McKellar Lake. It is primarily a shipyard, but also functions as a service area with repair shops, warehouses, storage yards, and administrative offices. Ensley Engineer Yard is designed to support the overall mission of the Memphis District. The District serves an area of approximately 25,000 square miles including portions of six states. District missions are directly related to navigation and flood control along 355 miles of the Mississippi River and its tributaries. Construction of Ensley Engineer Yard began in 1949. Marine repairs began in 1954. All major structures were complete and the yard was in full operation in 1962. A main feature of the yard is the mooring facilities, usually referred to as the “stringout” (Figure 12). The stringout is approximately 1.2 miles long and includes two floating drydocks.

The larger drydock is capable of holding a 2000-ton motor vessel. It is one of the largest floating drydocks on the Mississippi River north of New Orleans. During the “off season,” usually January through May, the District’s waterborne fleet is anchored at the yard for regularly scheduled maintenance and repairs. Between June and December, the fleet is normally engaged in routine channel maintenance and flood control projects. The fleet consists of the Motor Vessel Mississippi, a 217-ft twin-diesel powered towboat, which doubles as the flagship of the Mississippi River Commission, the dustpan dredge Burgess, towboats Strong and Goodwin, and four other floating units that make-up a revetment operation plant.

Figure 11. Overhead view of Ensley Engineer Yard.

Figure 12. Stringout at Ensley Engineer Yard.

The plant includes a quarterboat complex for housing and feeding workers, an articulated concrete mattress sinking unit, a mattress lading unit and a bank-grading unit. There are a number of other vessels both large and small supporting a variety of mission-oriented operations. Landside operations at Ensley Engineer Yard include modern shops and facilities. Machine, pipe, and plate shops support the District, along with electrical, carpentry, and electronic-telecommunications shops and operations. A heavy equipment shop is available for maintenance and repair on trucks, tractors, cranes, graders, and similar heavy-duty equipment. Warehouse facilities store a variety of items that range from construction materials to household supplies for shipboard use. Seventy full time employees work there year round and another 100 people are employed during the “off season” for maintenance and repair work.

The Ensley Engineer Yard contains 21 buildings with a total of nearly 116,000 sq ft. These include office space, maintenance shops, and various storage facilities. In terms of energy, there is nothing unique about these buildings other than possibly some of the machinery that is inside. Metal Brakes, rollers, cutters, welders, and other various equipment for repairing boat items is used in the repair facilities (Figure 13), but no ECMs for this type of equipment is feasible without affecting the mission. The buildings themselves are not unique and can be addressed similarly to those previously documented in various Energy Engineering Analysis Program (EEAP) studies (also known as EISA 432 Energy and Water Evaluations) as well as the “Field Guidance Package for Assessment of Energy and Water Conservation Opportunities at USACE Facilities.” The energy efficiency of the facilities visited was found to be in line with that of the facilities visited in the EEAP studies.

Figure 13. Various repair equipment at Ensley Engineer Yard.

When replaced with the more efficient systems now available, lighting systems generally offer a quick payback potential. Mechanical system replacement for energy conservation is sometimes attractive, but must be analyzed case by case. In general, the mechanical systems reviewed appeared to be maintained fairly well. However, re-commissioning is nearly always cost effective.

3.2.2 Energy consumption

Energy demand at Ensley Engineer Yard is fueled by a combination of natural gas and electricity with a small amount of diesel for emergency generators. Both the FY08 and FY10 CRAFT spreadsheets used a 40% GS and 60% GE ratio for estimating both natural gas and electricity use. Table 5 lists the energy consumption information reported in the CRAFT spreadsheet for FY08 and FY10.

Table 5. CRAFT reported energy consumption at Ensley Engineer Yard for FY08 and FY10

Energy Source	Year	GSor GE	Consumption (Units)	Consumption (MMBTU)	GHG Emission ($MTCO_2e$)
Natural Gas	FY08	GS	22,676 (CCF)	2,331	124
Natural Gas	FY08	GE	34,015(CCF)	3,497	186
Natural Gas	FY10	GS	20,673 (CCF)	2,125	113
Natural Gas	FY10	GE	31,009 (CCF)	3,188	169
Electricity	FY08	GS	1,686,000 (KWh)	5,754	1,162
Electricity	FY08	GE	2,529,000 (KWh)	8,631	1,742
Electricity	FY10	GS	1,104,000 (KWh)	3,768	761
Electricity	FY10	GE	1,657,000 (KWh)	5,655	1,142

The major GE energy consumers are the tugboats, dredgers (Figure 14), “Snaggers,” other various boats (Figures 15 and 16), and the flagship vessel *Mississippi* (Figure 17) that get their power from the “stringout” while docked at the shipyard. The total load varies with the number and type of vessels docked, but the service is 480 Volt 400 Amp 3-phase service, which equates to 332 kW.

Figure 14. A dredger.

Figure 15. A barge.

Figure 16. A fuel barge.

Figure 17. The flagship vessel *Mississippi*.

There is no sub-metering on the stringout. As a minimum ECM, the stringout should be sub-metered. Energy use varies with the vessel docked and any ECMs would be vessel specific. These same ECMs would also reduce vessel energy consumption when not docked. This level of analysis was beyond the scope of this project. Metering of each vessel's use while docked would be a very good step towards encouraging conservation on the vessels. Those found to be the largest users could be targeted for an energy audit.

3.3 Huxtable Pumping Plant

3.3.1 Description

The Huxtable Pumping Plant (Figure 18), located just outside Marianna, AK prevents floodwater from the Mississippi River from moving into the St. Francis River Basin and removes impounded water held back by the levee system. It is one of the largest plants of its kind in the world. The watershed served by this plant equals the size of the State of Delaware.

Figure 18. Huxtable Pumping Plant — downstream side.

3.3.2 Energy consumption

Energy demands at the Huxtable Pumping Plant are fueled by a combination diesel fuel and electricity. Both the FY08 and FY10 CRAFT spreadsheets used a 40% GS and 60% GE ratio for estimating electricity use. All of the diesel use was classified as GE. Table 6 lists the energy consumption information reported in the CRAFT spreadsheet for FY08 and FY10.

The major GE energy consumers are the 10, 3600 hp diesel driven pumps (Figures 19 and 20) and two 500 kW Caterpillar Gensets. The gensets are required because the utility electricity connection cannot provide enough energy when the pumps are operating. Other energy consumers include compressors, a small forced air furnace, four 7.5 hp gate motors, and two 20 hp compressors (Table 7).

Table 6. CRAFT reported energy consumption at Huxtable Pumping Plant for FY08 and FY10.

Energy Source	Year	GS or GE	Consumption (Units)	Consumption (MMBTU)	GHG Emission ($MTCO_2e$)
Diesel Fuel	FY08	GE	1,090,860 (gal)	150,539	11,171
Diesel Fuel	FY10	GE	608,900 (gal)	84,028	6,236
Diesel Fuel	FY11	GE	1,283,252 (gal)	176,951	13,131
Electricity	FY08	GS	113,000 (KWh)	386	53
Electricity	FY08	GE	170,000 (KWh)	580	79
Electricity	FY10	GS	127,000 (KWh)	433	59
Electricity	FY10	GE	190,000 (KWh)	648	88

Figure 19. Fairbanks Morse 3600 hp diesel engine.

Figure 20. Diesel engine turbocharger.

Table 7. Energy consuming equipment at Huxtable Pumping Plant.

Description	Number	Nameplate Data
Diesel Motor	10	3,600 hp; Fairbank-Morse Model #38TD81/8; 900 rpm
Gate Motor	4	7.5 hp
Compressor	2	20 hp; 88% Efficiency
Caterpillar Gen-Set	2	500 kW; 625 kVA; Model SR4

3.3.3 Fuel switching to biodiesel

The potential use of biodiesel was discussed with plant operators. They felt there were likely too many technical issues associated with the switching fuel types. The issues revolved around what would happen when old fuel was flushed from the system with biodiesel. However the details of the potential problems were not discussed.

Literature research since the site visit has shown that there may be potential in fuel switching. In fact, Fairbanks Morse Engine approved the use of 100% biodiesel in medium speed diesel engines in 2007 as long as the fuel meets American Society for Testing and Materials (ASTM) D6751 standards (see Appendix A). The approval announcement was for Opposed Piston (OP) Model 38D 8 1/8 diesel engines, which seem to match the type of engine used at Huxtable Pumping Plant. The approval announcement mentions several applications of Fairbanks Morse engines using biodiesel. One application involved the use of fish oil biodiesel (Steigers 2002). Another referenced study used biodiesel in large stationary diesel engines including tests on the same type of Fairbanks Morse engine used at Huxtable Pumping Plant (Kong and Kimber 2008).

Testing of biodiesel use in automotive and stationary diesel engines has shown benefits and drawbacks when compared to diesel use (USEPA 2002, NREL 2009, Sem 2004, Chiaramonti and Tondi 2003). The benefits include the reduction of accountable GHG emissions, reductions of carbon monoxide and particulate matter, and greater lubricity when compared to ultra low sulfur diesel fuel that is now required. The drawbacks include higher emissions of nitrogen oxides (NOx), some material incompatibilities with certain elastomers that may be used as gasket material, and the formation of injector tip deposits.

These issues primarily apply to 100% biodiesel (B100); the drawbacks are greatly reduced with 20% biodiesel blends (B20) and lower blends. The emission benefits and drawbacks vary with the biodiesel blend. Figure 21 shows this effect for heavy-duty automotive diesel engines. The issue of the cleaning effect of biodiesel noted by plant personnel as a potential problem is discussed in the NREL document. Biodiesel contains methyl esters that can dissolve sediments accumulated in fuel tanks and cause filter plugging. The effect is much smaller for B20 and lower blends; cleaning the tanks before the use of biodiesel will prevent this issue.

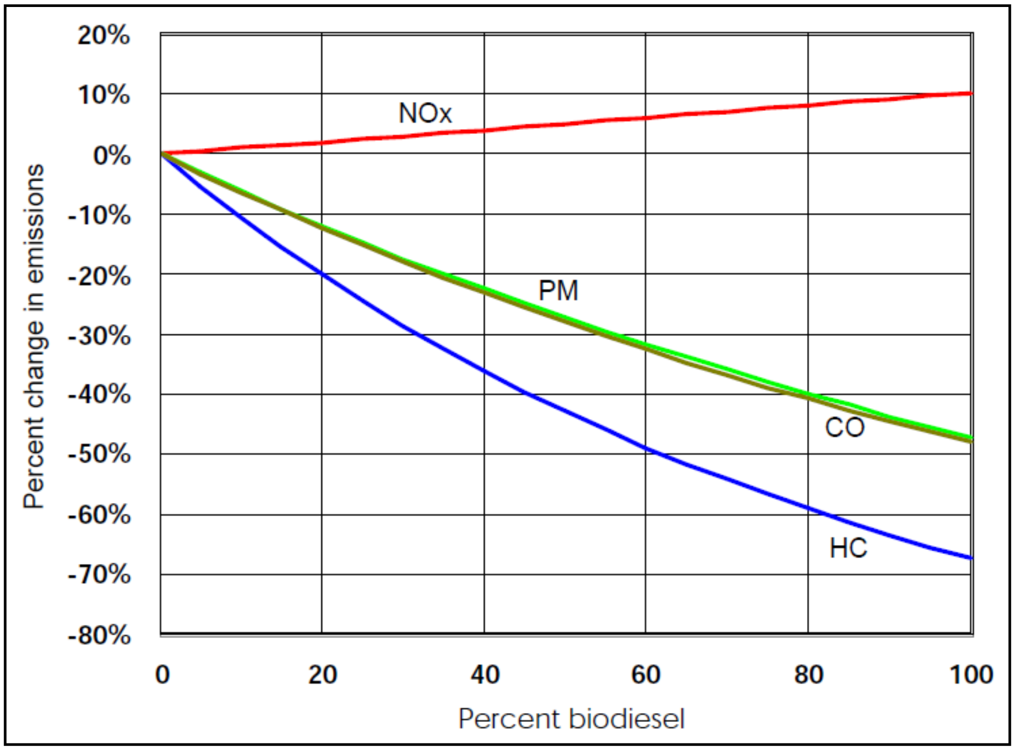

Figure 21. Average emission impacts of biodiesel for heavy-duty highway engines (EPA 2002).

Another property of biodiesel that could be considered a drawback is that is has about a 12% lower heating value than petro-diesel. Also, note that most studies have been conducted for the automotive industry and there is much less information available for large stationary diesel engines.

The potential GHG emission reductions that result from switching to biodiesel are great. As noted above, the GHG emissions from diesel fuel use at Huxtable Pumping Plant were 11,171 $MTCO_2e$, 6,236 $MTCO_2e$, and 13,131 $MTCO_2e$ for FY08, FY10, and FY11 respectively. In heavy use years such as FY08 and FY11, the use of B100 would offset about 10% of Corps-wide GS emissions and B20 about 2% of these emissions. The drawbacks of biodiesel conversion are not inconsequential, but the costs may be worth the potential of very large reduction in GHG emissions. Since B20 diesel fuel blend does not exhibit as many potential issues as B100, it may make sense to start a limited trial on one or more of the engines using B20. Potentially the largest issue is the increased NOx emission from biodiesel use. Huxtable Pumping Plant is installing a selective catalytic injection system to reduce NOx emissions. If a switch to biodiesel is considered, the effect of even a small increase in NOx on the emission control system must be taken into account.

As mentioned above, pollutant emissions are a function of the biodiesel blend. Figure 22 shows the effect of biodiesel blend on NOx emissions for some models of large stationary diesel engines. Of special note are the emissions from the engine “FM 1972,” which is a Fairbanks Morse engine that is similar to that used at Huxtable. The emissions show a modest NOx emission increase from pure diesel emissions even using a B100 blend.

3.3.4 Lighting and HVAC equipment

As with any building those at Huxtable Pumping Plant have lighting and HVAC equipment consuming devices. These are considered goal inclusive and are not considered in this report.

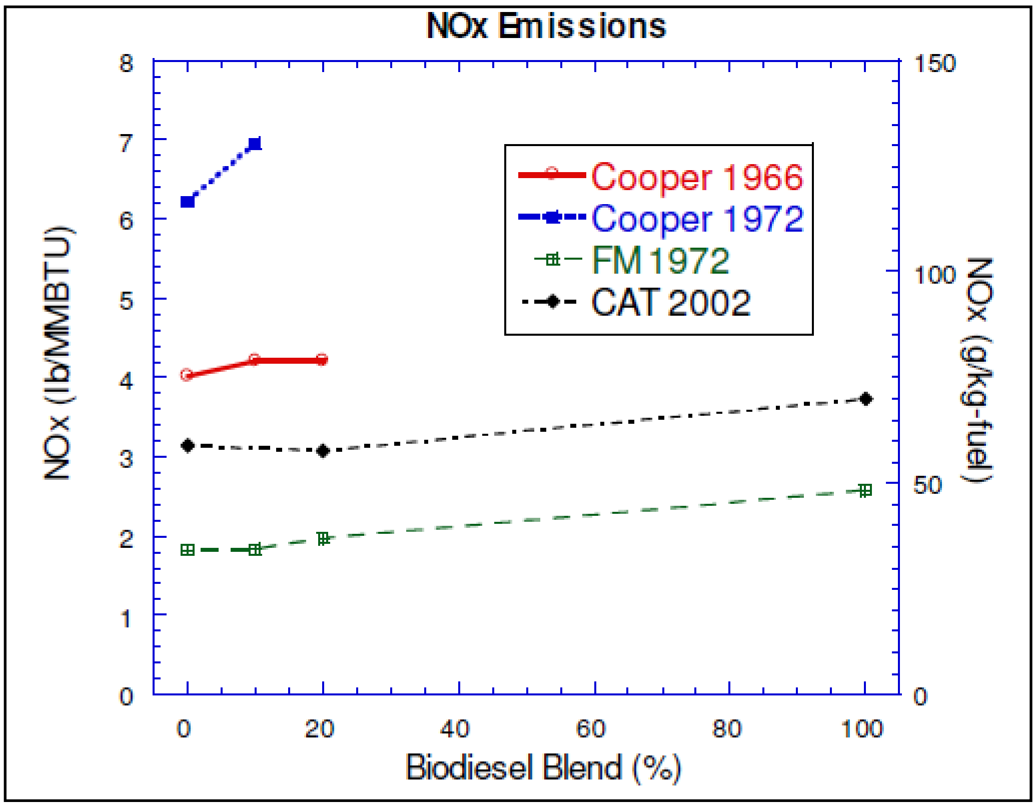

Figure 22. NOx emissions of various biodiesel blends (Kong 2008).

4 Conclusions and Recommendations

4.1 Conclusions

This work analyzed energy use and GHG emissions of USACE GE projects to determine USACE-wide results and the types of GE facilities that would present the greatest reduction opportunities. This analysis was based on data drawn from the Corps of Engineers Reduced and Abridged FEMP* Tool (CRAFT) spreadsheet submissions. The site types selected for visits were:

- *Pumping Stations*, due to their relatively large individual energy use
- *Locks and Dams*, because they are numerous and, as a group, large energy users
- *Repair Facilities*, because they use a fair amount of energy on an individual project basis.

Installations identified as representative sites for these three types, and thereby selected for site visits, were: Lock 27, Ensley Engineering Yard, and Huxtable Pumping Plant

This analysis concludes that:

- GE energy consumption and GHG emissions are similar to GS energy consumption and GHG emissions.
- The top 20 individual GE projects account for almost 72% of all GS GHG emissions (Table 1, p 5).
- Project types that are very specialized (i.e., ERDC laboratories, Washington Aqueduct, and the Chicago Fish Barrier) account for about 47% of overall Goal Exclude GHG emissions. However, GHG emission reduction strategies applied for the specialized projects would not be applicable at other Civil Works projects.
- When projects reporting GE energy consumption were assigned types, and the energy consumption and GHG emissions were then analyzed for each type (Table 2, p 6), the types “Lock and Dams,” “Pumping Plants,” and “Recreation Facilities” account for about 42% of all GE GHG emissions. Note that Recreation Facilities were not included as part of this study due to budget limitations, and to the relatively small energy use per facility.

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* Federal Energy Management Program (FEMP)

4.2 Recommendations

The largest GE energy consumers at the Lock facility (Lock 27 on the Mississippi) were electric motors. Although facilities with less efficient motors for valve and gate operations could benefit from motor retrofit, the electric motors at Lock 27 they were found to already be nearly as efficient as available Premium Efficiency motors. However, on motor failure, replacement with a high efficiency motor is recommended. Other ECMs recommended include HVAC re-commissioning and replacement upon failure by more efficient equipment, upgrades of interior and exterior lighting and associated controls, and upgrades of compressor controls.

The largest GE energy consumers at the Ensley Engineering Yard repair facility were the vessels docked and hooked up to the stringout for electrical power while docked. It is recommended to submeter the stringout and provide incentives for the vessels to minimize energy use. An energy audit of a representative sample of the vessels that are periodically docked there is recommended. Sub-metering of vessels is also recommended.

The largest GE energy consumers at the Huxtable Pumping Plant were the diesel-powered engines used to drive the pumps. Optimization of diesel engines and the associated pumps was beyond the scope of this project. Nevertheless, there may be potential for switching the diesel engines to biodiesel or biodiesel blends. It is recommended that a limited trial of the fuel switching be considered.

Acronyms and Abbreviations

Term	Definition
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
CASI	Center for the Advancement of Sustainability Innovations
CCF	100 Cubic Feet
CERL	Construction Engineering Research Laboratory
COL	Contingency Operating Location
CRAFT	Corps of Engineers Reduced and Abridged FEMP Tool
CRREL	Cold Regions Research and Engineering Laboratory
ECM	Energy Conservation Measure
EEAP	Engineering Energy Analysis Program
EIFS	Exterior Insulation Finishing System
EO	Executive Order
ERDC	Engineer Research and Development Center
FEMP	Federal Energy Management Program
GE	Goal Excluded
GHG	Greenhouse Gas
GS	Goal Subject
hp	horsepower
HPS	High Pressure Sodium
HQ	headquarters
HVAC	heating, ventilating, and air-conditioning
LED	light emitting diode
LPG	liquid petroleum gas
LRC	US Army Corps of Engineers — Chicago District
MMBTU	million Btu
MSC	Major Subordinate Command
$MTCO_2e$	million tonnes CO_2e
MVD	Mississippi Valley Division
MVK	US Army Corps of Engineers — Vicksburg District
MVM	US Army Corps of Engineers — Memphis District
MVN	US Army Corps of Engineers — New Orleans District
MVR	US Army Corps of Engineers — Rock Island District
MVS	US Army Corps of Engineers — St. Louis District
NAB	US Army Corps of Engineers — Baltimore District
NAD	US Army Corps of Engineers — North Atlantic Division
NEMA	National Electrical Manufacturers Association
NGRM	National Great Rivers Museum
NREL	National Renewable Energy Laboratory

Term	Definition
NSN	National Supply Number
OMB	Office of Management and Budget
OP	Opposed Piston
OPCO	Oppenheimer & Co. Inc.
SAR	Same As Report
SF	Standard Form
SR	Special Report
USACE	US Army Corps of Engineers
USEPA	US Environmental Protection Agency
WES	Waterways Experiment Station

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Appendix A: Fairbanks Morse Engine 2007 Biodiesel Use Approval Announcement

FAIRBANKS MORSE ENGINE
an EnPro Industries company

NEWS

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For immediate release

Fairbanks Morse Engine Approves 100% Bio-diesel for use in Medium Speed Diesel Engines

Beloit, Wisconsin, February 1, 2007 – Fairbanks Morse Engine, an EnPro Industries company, announced today the approval to utilize up to B100 (100% bio-diesel) in its Opposed Piston (OP) Model 38D 8 1/8 diesel and dual fuel engines for continuous operations. "Our extensive tests have demonstrated that utilizing B100 fuels that comply with the ASTM D6751 testing and specification had little impact on fuel consumption and power ratings, and had positive impacts on emissions by substantially lowering particulate matter (PM) and CO values", said Joe Eves, engineering manager – OP and FM/ALCO engines.

Commitment to the continuous growth of renewable fuels will play a major role in future policies and strategies for the U.S. and the world. As of Sept. 2006 86 plants were actively producing bio-diesel, with another 78 plants under construction or undergoing expansion in the U.S according to the National Biodiesel Board. "With a large installed base of Fairbanks Morse engines in the Midwest and throughout the U.S. our customers can now take full advantage of a renewable fuel source that in many cases is being produced just down the road", said Dan Bowman, vice president sales and marketing.

Bio-fuel usage in medium speed reciprocating engines is nothing new to Fairbanks Morse Engine. Experience ranges from Dutch Harbor, Alaska where UniSea, Inc utilizes up to 100% fish oil to power six Fairbanks Morse 2.3 MW generator engines to a Dupage County, IL cogeneration facility where digester gas is burned in a Fairbanks Morse 1.5 MW generator engine. In addition, San Francisco State University has been utilizing up to B80 since the late 1990s. Recently, Fairbanks Morse Engine concluded another successful test utilizing B100 (soy-diesel) in a continuous application in Story City, IA.

For specific engine applications and utilization contact Fairbanks Morse Engine.

About Fairbanks Morse Engine
Since the company's inception in the 1870s, Fairbanks Morse Engine, based in Beloit, Wisconsin, USA, has been a worldwide leader in diesel engine technology and manufacturing. Today, the mission of Fairbanks Morse Engine is to provide its customers the highest quality diesel engines and generator sets, dual fuel engine generator sets, OEM replacement parts, and factory trained direct field service support. Our focus markets today are in the stationary power generation sector and large medium speed diesel and diesel-electric propulsion for the United States Navy and commercial maritime shipbuilding industry.

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14. ABSTRACT
Executive Order (EO) 13514, *Federal Leadership in Environmental, Energy, and Economic Performance* expanded on the energy reduction and environmental performance requirements of EO 13423, *Strengthening Federal Environmental, Energy, and Transportation Management*. EO 13514 requires Federal agencies to set a Scope 1 and 2 greenhouse gas (GHG) emission reduction goal for fiscal year 2020 (FY20) based on an FY08 baseline. US Army Corps of Engineers (USACE) Civil Works projects include many common facility energy consumers such as office space, laboratory space, and visitor centers that are the focus of energy and GHG reduction strategies by many organizations. These "Goal Subject" (GS) energy consuming facilities support building operations and do not include facilities such as locks and dams and outdoor lighting, which are termed "Goal Excluded" (GE) facilities. USACE has many GE and non-building GHG emission sources such as those found at locks and dams; hydropower facilities; large pumping plants; fish barriers; canals, channels, harbors, and other navigation waterways; as well as docked vessels. This report documents a data analysis of GE energy consumption and GHG emissions and opportunities for reducing energy usage and GHG emissions based on site visits to three of these Civil Works project types.

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